Crib Work - An Evaluation Of A Problem-Based Learning Experiment: Preliminary Results

Vonda K. Walsh, Virginia Military Institute, USA
H. Francis Bush, Virginia Military Institute, USA

ABSTRACT

Problem-based learning has been proven to be successful in both medical colleges and physics classes, but not uniformly across all disciplines. A college course in probability and statistics was used as a setting to test the effectiveness of problem-based learning when applied to homework. This paper compares the performances of the students from two classes and attempts to draw inferences as to the overall benefits and effectiveness of changing the process by which the students earned their homework grade.

Keywords: Problem-Based Learning; Performance

INTRODUCTION

Problem-based learning is an instructional system that develops problem-solving skills and discipline knowledge by placing the student in the role of problem-solvers. The traditional roles of the instructor and student change and the student assumes more responsibility for their learning. In the 1960's, McMaster University Medical School developed and used problem-based learning to train graduate students at the medical school. Since then problem-based learning has been implemented at other medical schools and in various undergraduate programs around the world and there has been considerable discussion about the effectiveness of problem-based learning.

Various studies have compared the success of students exposed to problem-based learning to the success of students exposed to traditional instruction. Some studies have reported a decrease in success for problem-based learners (Albanese and Mitchell, 1993); some studies have reported that problem-based learners performed better than the traditional students (Schmidt, Dauphinee, and Patel, 1987; and Hake, 1998); and other studies have reported no statistical differences in the knowledge gain by problem-based learners as compared to students who received traditional instruction (de Vries, Schmidt, and de Graff, 1989).

During the spring 2011 semester, shortly before the fourth test, an instructor observed a group of students working collaboratively on their assigned homework. They were working in the departmental lounge area, known as the CRIB. Some of these students came to the instructor's office with questions and returned to the group where they shared their insights and knowledge with the other students in the CRIB. After the instructor graded the fourth test, it was apparent that some of the students had done particularly well. When the instructor congratulated the students on their performance, some of them attributed their success to their work in the CRIB. They indicated that they were glad they had studied together and they thanked the instructor for being available to answer questions. Their success prompted the instructor to study the applicability of problem-based learning in her classroom.

This paper compares the performance of students from two probability and statistics classes where the primary difference in the classes was the utilization of a mandatory problem-based student-centered study hall for one class but not for the other.

OVERVIEW AND HYPOTHESES

The traditional method of mathematics instruction generally has the instructor spend most of their time standing at a blackboard or a podium lecturing to the class and making minimal use of technology. The instructor presents the information and the students are viewed as "blank slates"; the students generally work alone and are expected to receive, understand, and retain the information.

In 1998, R. Hake analyzed the effectiveness of traditional lectures in introductory physics; his analysis (of over 6,000 students) shows that traditional lectures yielded an average normalized gain of 23 percent and that structured student-student interactions produced an average normalized gain of 48 percent. Hake also concluded there was relatively little difference in the quality of student learning and performance for those who received what was considered to be the best lectures as compared to those who received what was considered to be the worst lectures. Based on the minimal difference in student learning and performance, Dr. Hake concluded that efforts which focused solely on improving the quality of the lectures were not as fruitful as those that focused on transforming the pedagogy. In 2012, Sandhu, et al. concluded that while these didactic lectures are not ineffective, there were other methods of instruction that were at least as effective and were more likely to improve student performances.

A lecture can be used to provide an overview of a topic, but for students to develop a working knowledge of mathematics, they must work with mathematics. It is not enough for students to memorize procedures and formulas; they need to learn how to recognize when a procedure or formula is applicable and then apply it correctly. The knowledge and skills gain is greater when students learn mathematics through active participation than when it is taught to them and their involvement is more passive. When a class breaks into small groups, the class dynamics change. The students become more than "sponges" who absorb information or instruction. They receive and give information and instruction, and they interact with and process the information differently. This change of process encourages the students to assume more responsibility for their learning and it promotes active and more effective learning. In small-group settings within the classroom, the instructor may, and should, facilitate and guide the direction of learning by insuring the problems are appropriate and the students remain engaged. Small groups can provide a support system in which the students may feel more comfortable asking questions, making mistakes, listening and learning from their peers, explaining and teaching concepts or processes to peers, and applying their theories and discoveries.

Further, from past experience, the instructor found that the students who performed best generally scheduled formal study time for individual study or group study. They worked on assigned problems and they may have consulted with their peers or the instructor. The students who did poorly generally did not do the suggested homework, took inadequate notes, and had little or no peer support. With this in mind, the instructor designed the CRIB WORK study hall with a focus on collaborative study in a small discussion group setting. The study hall encouraged students to work cooperatively and to use the problems to develop their ability to apply mathematical thinking skills. The instructor maintained office hours and facilitated the study hall by assigning appropriate problems and being available during the CRIB WORK study hall.

METHODOLOGY AND DEVELOPMENT OF THE EXPERIMENTAL GROUP

Participants and Setting

For the past 27 years, the instructor has taught mathematics at a small liberal arts college located in rural Virginia and has an enrollment of approximately 1,600 students. She describes her teaching style as "very structured but student-teacher oriented." During the spring 2011 and fall 2011 terms, the instructor taught courses in probability and statistics for engineers. The course content was the same for both classes and the final grade was based on the results of four tests, the final exam, and a homework grade. All students had a graphing calculator. For each test, students were permitted to bring to each test and the final exam formulas on a 3"×5" index card. In both classes, the homework grade counted for 10% of the final grade; however, the process by which the student earned their homework grade differed in the two classes. There is some basis to infer that the process changes related to how the students earned their homework grades may have influenced the students' overall learning and their performance or achievement in the class. One instructor and two classes, for a total of 37 students, participated in the study.

The NoCRIB class involved 14 students and occurred during the spring term of 2011. This class did not have a mandatory CRIB WORK requirement and did not do CRIB WORK except for a short period that began before the fourth test during which time only part of the class did CRIB WORK unofficially.

The CRIB class involved 23 students who took the course during the fall term of 2011; the whole class had mandatory CRIB WORK for the entire semester.

There was no overlap in the student body of the two classes and the course content, lectures, four major tests, and final exam were the same in both classes[i]. The relative class size, the process by which the student earned their homework grade, and the student's learning and performances as measured on tests, were the only significant differences the instructor observed between the classes. This study only analyzed the grades obtained on the four tests and the final exam in these classes.

Motivation for the Process Change Related to Homework

The instructor has always maintained office hours and has always had some students who presented with questions and requests for assistance, but there have always been students who did not present with questions or requests for assistance. There have always been students who conscientiously did their assigned homework and those who did not do the assigned homework. There has often been a correlation between the student's ultimate success as measured by test performance and their efforts on homework assignments and requests for assistance.

At the beginning of the fall term, the instructor gave the new class the option of doing graded homework or participating in a study hall and doing CRIB WORK for the homework component of their grade. If they chose the CRIB WORK option, they would be required to spend a minimum of three hours per week in the CRIB working on assigned homework in blocks of time no less than 30 minutes. They would be allowed to work together and could seek help from the instructor. They would sign in and out of the CRIB to certify their participation. If they completed the minimum three hours each week, they would receive an "A" for their homework grade.

The instructor required the class to reach a consensus as to how everyone would earn their homework grade. Initially about half of the class preferred the CRIB WORK option and about half preferred the traditionally graded homework option. Relying on peer pressure, eventually all of the students agreed to the CRIB WORK option and the instructor agreed that if a student was unable to attend the CRIB - with legitimate reasons (sickness, interviews, etc.) - then special accommodations would be made. The instructor also agreed to keep some evening hours.

The CRIB

During the fall term, the CRIB class students were required to do their homework in an open-lounge area of the Mathematics Department. This area was called the CRIB (Figure 1) because of its appearance with railings and because it was common to find students sleeping within the area. The CRIB could easily accommodate 16 students with its eight individual study area and two round tables. When students signed in for their CRIB WORK, they could work alone or meet other students and work together on the assigned problems. They could also seek help from the instructor whose office was about 20 feet from the CRIB. Students signed in and out of the CRIB area and certified that they had worked on the assigned problems.

To test the hypotheses that students using the CRIB would outperform the other students, scores were compared from each of the four examinations and the final exam.

[i] The school maintains a high quality honor program which allowed the instructor to use identical test materials in both groups.

Figure 1: The CRIB

RESULTS

Test 1 covered descriptive statistics. Students typically find this to be one of the easiest parts of the course and the grade distribution bar charts indicate that both classes did relatively well on this material. Figure 2 demonstrates that both groups had "at-risk" (D's and F's) students, but there were more "at-risk" students in the NoCRIB group than in the CRIB Group (D's - 14.3% vs. 8.7% and F's - 7.1% vs. 4.3%), and for both classes, the percentage of "at-risk" students was less on Test 1 than on any other test or exam, except for the CRIB students on Test 3.

Levene's test for the equality of the variances showed no differences in the variances of the two groups ($n_C = 23$, $n_{NC} = 14$)[ii] with a $p = 0.49$. The t-test for independent samples provided $t = 0.428$ and a $p = 0.336$ and did not show a significant improvement for students performing CRIB WORK over those who had NoCRIB WORK. Although the results are not statistically significant, the t-value is positive and the graphs are consistent with the hypotheses.

The absence of significant difference in the performance of the two classes on Test 1 may have several explanations. First, the lack of statistical significance might have been caused by the level of difficulty of the test material. Second, the length of time before the first test is administered may have been a factor. Students need time to accept and adjust to the requirements of CRIB WORK. The sub-optimal participation during the adjustment period may also have contributed to the lack of a significant difference on Test 1. Initially, neither group placed a high value on completing the homework assignments. Although the fall class had agreed to the CRIB WORK option, initially some of the CRIB students complained about the mandatory study hall attendance. Some of these students were conscientious about their study habits and saw no benefit in or reason for the requirements to sign in and out to certify their participation. Some had poor study habits and were not accustomed to doing homework or studying on a regular and consistent basis. The students were reminded that they had agreed to the CRIB WORK option and after an adjustment period, the CRIB students accepted their obligations, developed their patterns, and did their mandatory CRIB WORK.

[ii] The subscripts "c" and "nc" refer to CRIB WORK and NoCRIB WORK students, respectively.

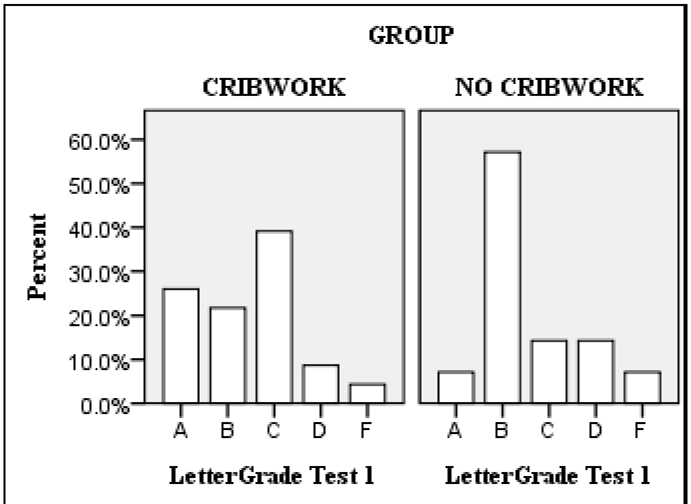

Figure 2: Test 1

Test 2 material covered probability theory. Many students from both groups found this material to be more difficult. Figure 3 shows that the proportion of the "at-risk" students increased in each group. The proportion of "at-risk" students in the CRIB WORK class increased from 13% to 26% while the number of "at-risk" students in the NoCRIB WORK class increased from 21.4% to 42.8%. It is interesting to note the number of "at-risk" students grew at the same rate in both groups. The number of successful students (A's and B's) grew at a substantially higher rate for the CRIB WORK students (47.8 % up to 56.5%) than that for the NoCRIB WORK students (64.2% down to 35.7%).

Levene's test for the equality of the variances showed no differences in the variances of the two groups ($n_C = 23$, $n_{NC} = 14$) with a p =0.705. The t-test for independent samples indicated that students in the CRIB WORK class performed significantly better than the students in the NoCRIB WORK class; t = 1.840 and p = 0.037.

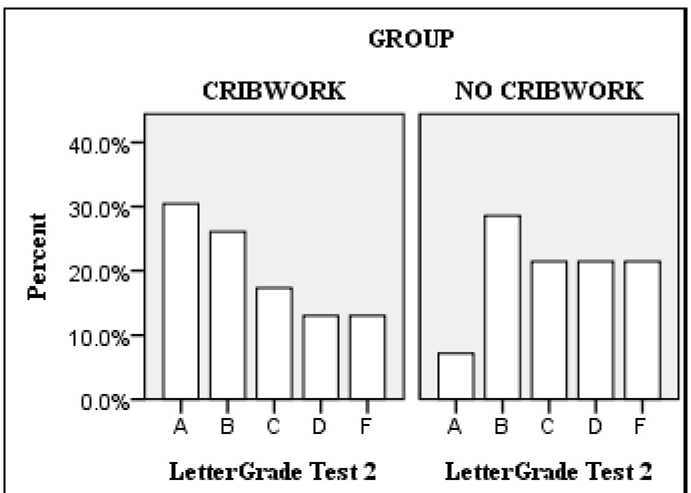

Figure 3: Test 2

Material on Test 3 covered distribution theory. This is probably the most difficult material in the course; most students find this material to be very difficult. While the distribution of the NoCRIB WORK students still looks fairly uniform, Figure 4 shows the CRIB WORK students were experiencing a steady increase in their letter grades.

Levene's test for the equality of the variances showed no differences in the variances of the two groups ($n_C = 23$, $n_{NC} = 14$) with a $p = 0.056$. The t-test for independent samples indicated that students in the CRIB WORK class performed significantly better than students in the NoCRIB WORK class; t-value = 2.242 and $p = 0.016$.

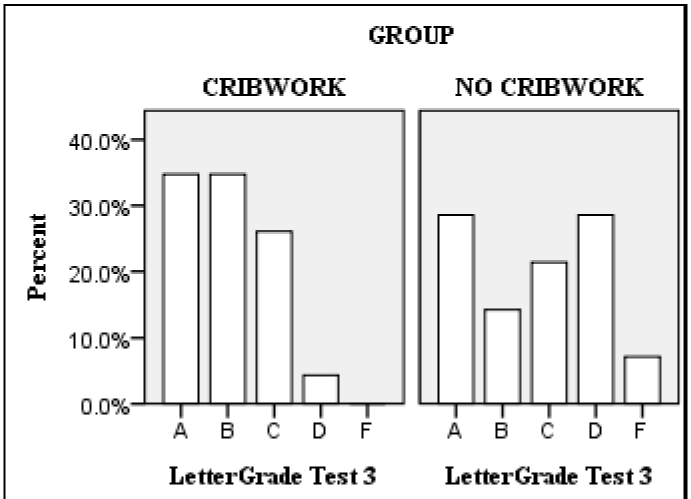

Figure 4: Test 3

The material on the fourth test covered statistical inference. The results from Test 4 showed no significant difference in the performances of the two groups of students, which does not support the hypotheses. Although, a significant statistical result did not occur, Figure 5 shows the tendency for students using the CRIB to outperform their counterparts.

Levene's test for the equality of the variances indicated a difference in the variances of the two groups ($n_C = 23$, $n_{NC} = 14$) with a $p = 0.044$. The t-test for independent samples did not indicate that students in the NoCRIB WORK class performed significantly better than the students in the CRIB WORK class; t-value = -0.714 and p = 0.242.

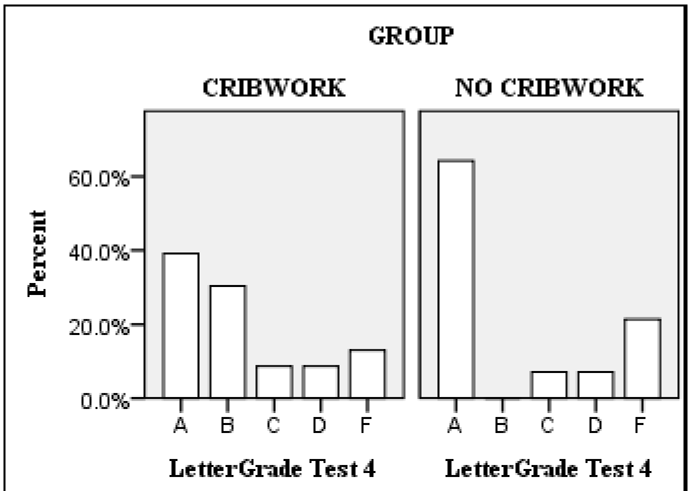

Figure 5: Test 4

At first blush, these results do not seem to support the hypothesis that CRIB WORK students out-perform NoCRIB WORK students; but in actuality, some of the NoCRIB WORK students were those whose work in the departmental CRIB had prompted the investigation of this student problem-based homework experiment. Levene's results of a statistical difference in the variances of the two groups may be due to the fact that some NoCRIB WORK students initiated problem-based learning on their own in the CRIB. About half of the students in the NoCRIB class had worked together in the CRIB before the fourth test. Further, the distribution of letter grades (Figure 5) suggests that if you start the collaborative study process too late, the "at-risk" students will likely remain "at-risk".

The final exam was comprehensive and, once again, the CRIB WORK students outperformed the NoCRIB WORK students. The CRIB WORK students were more proficient in problem-solving, self-learning, and group participation. Additionally, the results of the t-test, along with the distribution (Figure 6), indicated that over the course of the semester, CRIB WORK students may have retained more information than the NoCRIB WORK students.

Levene's test for the equality of the variances showed no differences in the variances of the two groups ($n_C = 23$, $n_{NC} = 14$) with a $p = 0.705$. The t-test for independent samples indicated that students in the CRIB WORK class performed significantly better than students in the NoCRIB WORK class; t-value = 3.297 and $p = 0.001$.

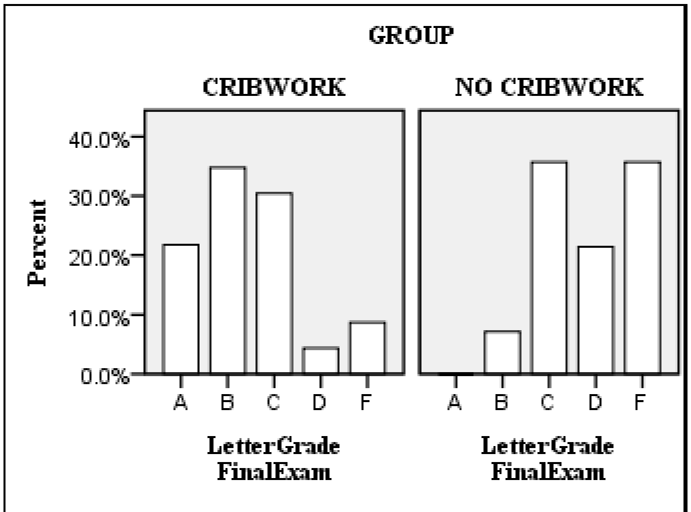

Figure 6: Final Exam

CONCLUSIONS

In this small case study, findings indicated that problem-based learning is effective in developing problem-solving skills and in promoting long-term retention for material covered in probability and statistics courses; however, there are limits to what can be generalized from a single case study. A major difference between the NoCRIB class and the CRIB class was how the students interacted with each other. The CRIB students planned their work time and decided which problems they would do in the CRIB, and even after they satisfied the mandatory 3-hour minimum, some CRIB students stayed in the CRIB and continued to work. The CRIB students visited the instructor for help more than the NoCRIB students. Simply put, mandatory CRIB time improved the students learning, but the learning did not stop when the student stepped out of the CRIB. Students continued to discuss problems outside of class and outside the CRIB. More work needs to be done in analyzing the group dynamics, assessing the quality of the problems, evaluating the role of the instructor as facilitator of the CRIB WORK, and considering the role of the lecture before we fully understand the impact of problem-based learning on students' study habits and their success.

AUTHOR INFORMATION

Dr. Vonda K. Walsh is a Professor of Mathematics at Virginia Military Institute. She received her B.S. in Mathematics from the University of Virginia's College at Wise, her M.S. in Pure Mathematics from Virginia Tech and her Ph.D. in Biostatistics from the Medical College of Virginia /Virginia Commonwealth University School of Medicine. E-mail: walshvk@vmi.edu (Corresponding author)

Dr. H. Francis Bush is a Professor of Economics and Business at the Virginia Military Institute. He received a B.A. in Mathematics from the State University of New York at Buffalo, NY, his Masters of Accountancy from The Ohio State University and his PhD from the University of Florida. The focus of his doctoral work was human information processing and is currently investigating ways to improve educational experiences. At VMI he teaches Principles and Intermediate Accounting, Financial Statements Analysis, and Statistics. E-mail: bushhf@vmi.edu

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